RECONFIGURABLE GROUND STATES IN VORTEX-BASED MAGNONIC CRYSTALS

Shikha Jain, Valentyn Novosad, F. Y. Fradin, John Pearson, and Samuel Bader
Materials Science Division
Argonne National Laboratory, 9700 South Cass Ave., Argonne, IL 60439

INTRODUCTION

Vortices are observed in the statics and dynamics of a variety of physical systems, such as fluids and plasma, optics, superconductors and magnetic materials. In patterned mesoscopic ferromagnets, the ground state of the static magnetization can have a form of a vortex that consists of a large region of in-plane curling magnetization and a vortex core region with out-of-plane magnetization. In a magnetic dot that has a single vortex-state, the eigenfrequency of the gyrotropic oscillations of the vortex core for both directions of the core polarity ($p = \pm1$) is the same [1]. By contrast, in an array of coupled elements, the dynamic dipolar interaction eliminates this frequency degeneracy and results in collective gyrotropic excitations with different eigenfrequencies that depend on both the relative polarities and chiralities of the individual vortices. Consequently, dynamic interactions between coupled vortex cores has attracted immense research focus as it has the potential in vortex-based logic devices, vortex-based magnonic crystals for information propagation, vortex-based spin torque nano-oscillators for microwave emission and even in bio-medical applications. In this work, we demonstrate an effective method for controlling the relative vortex core polarities in a model system of connected (slightly overlapping) vortex-state permalloy ($Ni_{80}Fe_{20}$) magnetic dots. This method also permits the effective selection of a specific dynamic mode of microwave absorption.

EXPERIMENTAL DETAILS

The samples were fabricated using electron-beam lithography and lift-off processes. The double-dot structure has dimensions of 2 x 1 µm with vertical contact length of 740 nm and thickness 48 nm. In order to measure the resonance frequencies of the gyrotropic modes, the structures were fabricated on top of a shorted Cr (10 nm) / Au (300 nm) coplanar waveguide (CPW) with a 3-µm wide signal line. Microwave measurements were performed in reflection mode using a vector network analyzer (VNA) as the current source.

RESULTS

The absorption spectrum for the as-grown sample at remanence for -15 dBm of input microwave power (P_{Low}) is shown in Fig. 1(c). The two absorption peaks in Fig. 1(c) correspond to opposite ($p_1p_2 = -1$) and same ($p_1p_2 = +1$) polarity combinations. The eigenfrequencies of these two combinations are 265 MHz ($\omega_{\uparrow\downarrow}$) and 305 MHz ($\omega_{\uparrow\uparrow}$), respectively [2].

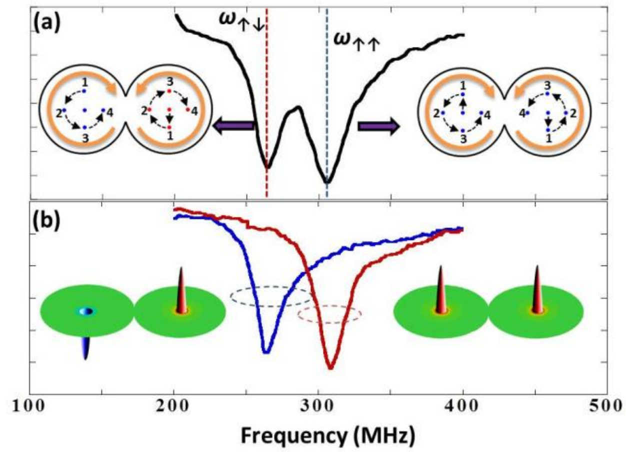

Figure 1. (a)Absorption spectrum with two resonance peaks corresponding to a polarity product of $p_1p_2 = -1$ and +1, respectively. (b) Absorption spectra after high *rf*-amplitude treatment at fixed frequency $\omega_{\uparrow\downarrow}$ (red curve) or $\omega_{\uparrow\uparrow}$ (blue curve).

To demonstrate mode selectivity, the paired structures were driven at a high microwave power of 10 dBm at the resonance frequency of one of the collective modes. When the power was subsequently reduced to a minimum accessible value (as used to probe vortex excitations in the linear regime) only one absorption peak, which corresponds to the second collective mode, was observed in the frequency spectrum. This result indicates that when the system is excited by a large-amplitude signal at the frequency $\omega_{\uparrow\downarrow}$, followed by a reduction of the driving amplitude, the system then relaxes to a ground state that corresponds to the other mode with frequency $\omega_{\uparrow\uparrow}$, and vice versa. Representative absorption spectra for two different excitation frequencies, $\omega_{\uparrow\downarrow}$ (red curve) and $\omega_{\uparrow\uparrow}$ (blue curve), are shown in Fig. 1(b). This technique of controlling the ground state and the dynamic excitation mode in a model system of paired disks can be readily extended to a system of n-coupled vortices that form a magnonic crystal.

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